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IMPROVING THE YIELD OF CANARIO

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"IMPROVING THE YIELD OF CANARIO"

Final Report
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ABSTRACT

Canaryseed acreage in Saskatchewan has increased by 75% over the last decade, exceeding 700,000 acres in 2004. One of the major objectives of research on canaryseed conducted at the University of Saskatchewan has been to find alternative uses for the crop. As a first step we have bred out the potentially harmful trichomes (hairs) on the canaryseed hull. The first glabrous Canaryseed (Canario ™) cultivar, CDC Maria, is 10-15% lower yielding than pubescent-hull cultivars. This yield differential has limited the adoption of Canario. The key objective of this project was to reduce or eliminate the yield gap between glabrous and pubescent canaryseed types.

During the course of this project 50 replicated field trials were conducted in order to identify higher-yielding Canario lines. Furthermore, populations ranging from the F2 to the F6 generations were evaluated and advanced for agronomic evaluation. Severe drought conditions during the first two years (2001 and 2002) of this project resulted in very low grain yields (50-100kg/ha) in the nurseries where primary yield selection was performed. The growing conditions in 2003 resulted in yields that were 25-30% below average but provided more meaningful test results. In 2004 near-record high yields were achieved (2,400 kg/ha), allowing for good yield potential expression. Despite these widely divergent growing conditions, a number of promising lines were identified and one variety was released.

One of the higher yielding lines identified after five years of testing, C99048, was registered as the variety CDC Togo in June, 2004. CDC Togo yielded, averaged over 31 trials in Saskatchewan, 13% higher than CDC Maria and produced heavier seed. Thus, CDC Togo appears to have closed the yield gap between glabrous and pubescent canaryseed varieties.

In addition to brown-seeded glabrous material, promising yellow-seeded glabrous lines were identified. A number of yellow-seeded lines appeared to yield nearly 10% higher than CDC Togo but tended to be later maturing (by four days) and taller (5 to 9 cm). Thus, it appears that we can achieve further yield gains, but there is a trade-off between yield and crop maturity and straw length.

INTRODUCTION

Canaryseed acreage in Saskatchewan has increased by 75% (1999-2003) compared to 1989-1993, exceeding 700,000 acres in 2004. The continuing increase in production is not matched by an increase in market demand, resulting in depressed prices. One of the major objectives of research conducted at the University of Saskatchewan has been to find alternative uses for the crop. As a first step we have bred out the potentially harmful trichomes (hairs) on the canaryseed hull.

The first glabrous Canaryseed (Canario ™) cultivar, CDC Maria (registered in 1997) is 10-15% lower yielding than pubescent-hull cultivars such as Keet and Elias (Hucl et al. 2001). This yield differential has limited the adoption of Canario. Furthermore, yield gains in other crops have put canary seed at an economic disadvantage.

The key objective of this project was to reduce or eliminate the yield gap between glabrous and pubescent canaryseed types.

Using AFIF funding that expired in early 2001 we developed experimental lines that yielded 9-12% higher than CDC Maria (based on tests conducted in 1999 and 2000). In order to eliminate the yield gap, further agronomic evaluation and breeding progress was required. We planned to use standard breeding methodology to develop higher-yielding glabrous canary seed germplasm.

Methods

Standard small plot techniques were utilized in the evaluation of Canario experimental lines. In most cases, the experimental design was a Balanced (6x6) Lattice with three replications for the replicated tests.

Individual plots consisted of four rows 3.6-m long at the Seed Farm, Kernen, Preston and Elrose sites. The plots at Scott were slightly larger (20%) than indicated above while those at Indian Head were approximately five times larger. Rows were spaced 0.2 to 0.3-m apart. Plots were sown at a rate of 250 seeds m^{-2}. Fertilizer was drilled in with the seed at recommended rates to supply sufficient levels of N-P-K. Weeds were controlled using herbicides and, when necessary, hand-hoeing. Data were collected for days to heading (50% spike emergence), days to maturity (95% physiological maturity), and plant height. Plots were combine-harvested at maturity and grain samples were dried using forced air driers. Data were collected on grain yield, test weight and 1000-kernel weight. Statistical analyses were conducted using Agrobase or Minitab (V13). Unreplicated yield trials consisted of 31 experimental lines (Standard plot size) with five plots of the check variety equally distributed across the test. The unreplicated tests were handled in the same manner as the replicated tests in terms of data collection.

In 2001 the most advanced breeding lines (a total of 157) in the Canario breeding program were evaluated in a series of replicated (n=3) yield trials. The lines were initially yield tested in 1999 or 2000.

In 2002 the most advanced breeding lines (a total of 120) in were evaluated in a series of four replicated (n=3) yield trials. Of the 120 lines, 30 were selected from trials conducted in 1999, 2000 and 2001.

In 2003 the 165 most advanced breeding lines were evaluated in a series of four tests. In 2004, 120 lines were evaluated in four tests.

The 2001-2004 tests in question and their description are summarized as follows:

Test	Site	Cooperator	fate	CV%
2001CANYT1	Kernen	Hucl	droughted out	-----
2001CANYT1	Seed Farm	Hucl	harvested	14.2
2001CANYT1	Elrose	Hucl	lost to uneven stand/weeds	----
2001CANYT1	Scott	Kapiniak (AAFC)	harvested	10.3
2001CANYT1	Indian Head	May (IHARF)	harvested	12.9
2001CANYT2	Kernen	Hucl	droughted out	-----
2001CANYT2	Seed Farm	Hucl	harvested	26.9
2001CANYT3	Kernen	Hucl	droughted out	-----
2001CANYT3	Seed Farm	Hucl	harvested	15.9
2001CANYT4	Kernen	Hucl	droughted out	46.1
2001CANYT5	Kernen	Hucl	harvested	31.0
2002CANYT1	Kernen	Hucl	harvested	34.3
2002CANYT1	Seed Farm	Hucl	harvested	18.9
2002CANYT1	Scott	Kapiniak (AAFC)	harvested	7.6
2002CANYT1	Indian Head	May (IHARF)	harvested	7.3
2002CANYT1	Preston	Hucl	harvested	52.3
2002CANYT2	Kernen	Hucl	droughted out/weeds/grasshoppers	-----
2002CANYT2	Seed Farm	Hucl	harvested	13.6

2002CANYT3	Kernen	Hucl	droughted out/weeds/grasshoppers	-----
2002CANYT3	Seed Farm	Hucl	harvested	13.5
2002CANYT4	Kernen	Hucl	droughted out/weeds/grasshoppers	-----
2002CANYT4	Seed Farm	Hucl	harvested	12.4
2002Regional	Redvers	Heal	harvested	35.0
2003CANYT1	Kernen	Hucl	harvested	7.6
2003CANYT1	Seed Farm- D1	Hucl	harvested	8.3
2003CANYT1	Seed Farm- D2	Hucl	harvested	7.7
2003CANYT1	Scott	Kapiniak (AAFC)	harvested	8.4
2003CANYT1	Indian Head	May (IHARF)	harvested but high CV	34.3
2003CANYT2	Kernen	Hucl	harvested	7.4
2003CANYT2	Seed Farm	Hucl	harvested	9.7
2003CANYT2	Scott	Kapiniak (AAFC)	harvested	8.0
2003CANYT3	Seed Farm	Hucl	harvested	7.5
2003CANYT3	Scott	Kapiniak (AAFC)	harvested	6.7
2003CANYT4	Seed Farm	Hucl	harvested	10.6
2003CANYT4	Scott	Kapiniak (AAFC)	harvested	16.0
2003CANYT5	Seed Farm	Hucl	harvested	5.2
2003CANYT5	Scott	Kapiniak (AAFC)	harvested	18.3
2004CANYT1	Kernen	Hucl	harvested	10.4
2004CANYT1	Seed Farm- D1	Hucl	harvested	7.7
2004CANYT1	Seed Farm- D2	Hucl	harvested	5.1
2004CANYT1	Scott	Kapiniak (AAFC)	harvested	9.2
2004CANYT1	Indian Head	May (IHARF)	harvested	11.9
2004CANYT2	Kernen	Hucl	harvested	7.6
2004CANYT2	Seed Farm	Hucl	harvested	5.7
2004CANYT2	Scott	Kapiniak (AAFC)	harvested	7.9
2004CANYT3	Kernen	Hucl	harvested	9.5
2004CANYT3	Seed Farm	Hucl	harvested	5.7
2004CANYT3	Scott	Kapiniak (AAFC)	harvested	6.7
2004CANYT4	Seed Farm	Hucl	harvested	10.6
2004CANYT4	Kernen	Hucl	harvested	10.0

CV(%) = Coefficient of Variation.

Results

(A.1) Advanced yield trials

The drought conditions in 2001 resulted in the loss of two out of 5 sites for CANYT1. This trial consisted of our most advanced breeding lines. The yields at the Kernen site were in the vicinity of 50 kg/ha (approx. 1 bu/ac). The yields at the sites with usable data were in the 600 to 1300 kg/ha range. The trials that were grown at Kernen only (2001CANYT4 and CANYT5) were harvested in order to provide seed for re-testing in 2002. The CV's for the Kernen site were in excess of 30%.

The 2002 crop season was the poorest on record for the Saskatoon region. The growing conditions were poorer than in 2001. No rainfall in May was followed by rainfall in mid-June and July which resulted in late flushes of weeds such as wild millet which were difficult to control. High temperatures during heading resulted in a very high frequency of sterile panicles. Trials at the Kernen Farm were damaged by grasshoppers. Late flushes of panicles were subjected to frost damage. The drought conditions in 2002

resulted in the out-right loss of three trials and excessive CV's resulted in the loss of a further three trials (CV>20%). The 2002 yields at the Kernen site were in the vicinity of 100 kg/ha (approximately 2 bu/ac). The yields at the sites with usable data had grain yields in the 600 to 1800 kg/ha range. The 2002 Preston site at Saskatoon was irrigated but the weed populations were extremely high. The Seed Farm site received in excess of 100 mm of irrigation. However, heat stress and late flushes of weeds at that site limited the yield achieved (700-800 kg/ha). This site was heavily infested with wild millet and required multiple herbicide applications.

A seed purification plot was produced for each yield trial entry. This seed was subsequently used for setting up the 2003 trials. Seed purification plots were subsequently produced in 2003 and 2004. The canaryseed plots were separated by plots of dwarf wheat in order to minimize mechanical admixtures during the seeding and combine-harvesting procedures.

The 2003 crop season in the Saskatoon region was a marked improvement over 2002. We received 50-60 mm of rain in April and another 50 mm in early July. The remaining months saw below-normal rainfall. However, the timely rainfalls meant that yields were reduced by approximately 30% compared to the long-term average not the 75-90% reductions we saw in 2002. Average grain yields at the Seed Farm and Kernen sites were 1,800 and 900 kg/ha, respectively.

In contrast to 2002, all except one trial in 2003 had acceptable CV's (<20%). The much lower environmental error combined with higher grain yields allowed us to select lines with a greater degree of confidence than in 2002. The Seed Farm site received approximately of 100 mm of irrigation.

The 2004 growing season represented a complete reversal of the conditions experienced during the preceding three years. The cool and wet growing conditions resulted in record high yields at the Seed Farm site (2,300 kg/ha) with a mid-May planting. At the Kernen site yields were in the intermediate range (1,400 kg/ha). The Kernen site was typically seeded a week later than the Seed Farm site during the course of this project.

In order to summarize the salient results of our breeding efforts up to 2001, multi-year data for two groups of lines (C99000 and C00000 series) is presented in Tables 1 and 2. The lines with a C99 designation were first tested in replicated trials in 1999 and C00 lines were first evaluated in replicated trials in 2000. The yield is expressed as a percent of the CDC Maria check and the other traits in relative (+/-) terms.

Table 1. Multi-year averages (1999-2001) for Canario lines in the C99000 series.
Data is presented relative to CDC Maria.

Trt #		GY %	DSE days	DPM days	HT cm	LBL 1-5	LDG 1-9	TWT kg/hL	KWT grams
1	CDC Maria	100.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	C99005	104.6	0.7	0.1	-0.5	0.0	-0.0	-0.5	0.2
3	C99018	105.4	-1.3	1.1	2.2	0.1	0.0	-0.7	0.2
4	C99037	112.6	0.5	0.1	1.6	-0.1	-2.3	1.0	0.2
5	C99048	106.5	2.0	1.1	-0.5	-0.1	-2.3	-1.8	0.1
6	C99049	107.3	1.1	1.6	-1.7	-0.4	0.0	-0.3	0.2
7	C99050	110.7	2.1	1.5	2.0	-0.7	-2.3	-1.4	0.3
8	C99052	106.9	1.8	2.2	0.3	-0.5	-0.6	-0.3	0.3
9	C99060	107.2	0.1	1.2	-1.3	-0.4	-0.3	-1.2	0.3
	# of trials =	11	6	6	7	3	1	1	1

DSE = days to spike emergence; DPM = days to maturity; HT = plant height;
LBL = leaf mottle severity; LDG = lodging; TWT =test weight, KWT = 1000 kernel weight.

After three years of testing (1999 to 2001) over 11 trials, two lines (C99037 and C99050) maintained a yield advantage of 10% over CDC Maria. Other lines selected on the basis of high yield in 1999-2000; yielded 5-7% higher than CDC Maria (Table 1). One line, C99050, also appeared to have a slight improvement in tolerance to the leaf mottle pathogen.

Table 2. Multi-year averages (2000-2001) for Canario lines in the C00000 series.
Data is presented relative to CDC Maria.

Trt#		GY	DSE	DPM	HT	LBL	TWT	KWT
		%	days	days	cm	1-5	kg/hL	grams
1	CDC Maria	100.0	-0.0	0.0	0.0	0.0	0.0	0.0
10	C00007	114.3	2.8	1.6	-0.8	-0.3	1.4	-0.1
11	C00008	111.5	0.9	0.2	-1.3	0.0	1.1	-0.3
12	C00009	106.5	1.2	0.3	1.3	-0.3	0.8	-0.3
13	C00010	108.6	1.7	1.0	2.3	-0.2	0.4	-0.1
14	C00011	111.2	2.4	0.9	4.4	-0.1	1.0	-0.0
15	C00014	112.5	3.3	0.6	3.0	-0.6	2.6	-0.6
16	C00015	113.7	1.7	1.2	5.5	0.1	0.3	-0.1
17	C00016	105.7	1.8	1.3	-0.7	-0.1	0.6	-0.5
18	C00018	118.9	2.5	1.9	-2.9	-0.8	-0.5	0.0
19	C00022	117.1	1.7	0.7	3.5	-0.4	1.6	-0.2
20	C00023	110.1	1.9	1.2	5.5	-0.5	1.0	-0.1
21	C00024	115.0	1.8	1.0	4.2	-0.3	0.3	0.0
22	C00026	117.2	2.0	0.7	3.4	0.2	0.4	-0.0
23	C00030	120.9	2.6	0.8	4.4	-0.1	1.2	0.0
24	C00032	108.0	1.5	0.5	4.5	0.1	1.3	-0.3
25	C00033	116.2	2.2	1.2	2.5	-0.5	0.1	0.1
26	C00034	122.0	1.2	0.7	2.6	0.1	0.8	-0.1
27	C00035	123.5	1.8	-1.1	9.9	-1.5	1.0	-0.1
28	C00036	109.5	1.7	-0.3	7.5	-1.0	2.2	-0.4
29	C00038	120.7	1.2	-0.9	4.3	-0.6	-0.8	-0.1
30	C00040	115.9	0.5	-1.4	3.5	-0.9	-0.2	-0.2
31	C00041	123.4	-0.2	-1.9	2.0	-0.6	0.1	-0.1
32	C00043	112.7	1.3	-0.4	8.6	-1.2	-1.0	-0.1
33	C00046	118.4	1.3	-1.1	8.8	-1.7	0.7	-0.1
34	C00051	109.4	1.0	-0.8	8.1	-0.6	0.6	-0.1
35	C00057	110.5	1.7	-0.9	13.3	-0.4	1.3	-0.1
36	C00060	103.8	2.7	0.4	11.2	-1.1	-0.2	-0.1
	# of trials =	6	4	4	4	3	1	1

DSE = days to spike emergence; DPM = days to maturity; HT = plant height;
LBL = leaf mottle severity; LDG = lodging; TWT = test weight, KWT = kernel weight.

Of the lines first evaluated in replicated trials in 2000 (series C00000), twelve yielded 15% or higher than CDC Maria (Table 2). Of the lines in the C01000 series, 23 out of 105 were selected for further evaluation in 2002 (data not presented).

The results for the most advanced lines tested in 2002 are presented in Table 3. Multi-year data for the C99000 series of lines is presented in Table 4. The yield is expressed as a percent of the CDC Maria check and the other traits in relative (+/-) terms. The data needs to be interpreted with caution. However, lines that visually looked more productive in the field also were higher yielding. Of note were new entries such as code#35. Test weights and kernel weights were measured on lines advanced to 2003 yield trials. All lines were within 2 kg/hL units of CDC Maria for test weight 1.0 gram for 1000 kernel weight. The line C99037 continued to perform well in 2002 (Table 3) as well as averaged over the four years of testing in a total of 16 useable trials. Averaged over the 16 trials C99037 yielded 15% higher than CDC Maria.

Table 3. 2002 data for advanced Canario lines grown at five sites. Data is presented relative to CDC Maria.

	Entry	Pedigree	GY	DSE	HT	LDG	Seed type
1	CDC Maria		100.0	0.0	0.0	0.0	GB
2	C99005	Maria x CY184	99.9	-0.5	1.3	-0.1	GY
3	C99037	Maria x CY184	120.4	0.2	3.0	-0.2	GB
4	C99048	Cantate x Maria	110.2	1.0	5.0	-0.1	GB
5	C99050	Cantate x Maria	114.8	0.0	2.8	0.0	GB
6	C00026	Maria x CY193	111.7	0.3	6.1	-0.2	GY
7	C00030	Maria x CY193	119.9	-0.3	3.0	0.1	GY
8	C00034	Maria x CY193	137.0	-0.3	-0.5	0.8	GY
10	C00038	Maria x 46	123.0	0.0	-2.6	2.3	GB
12	C00046	Maria x 27	113.5	-0.5	0.7	0.9	GB
13	C00091	Maria x 47	115.5	0.5	3.5	1.0	GB
14	C01006	Maria x 27	115.6	-0.3	-0.8	1.7	GB
16	C01014	Maria x CY15	117.6	0.7	1.2	0.9	GB
19	C01025	Mr/CY184//Mr/Cta	116.3	-0.2	2.3	0.0	GY
28	C01061	Maria x CY193	125.6	-0.3	2.9	1.1	GY
29	C01062	Maria x CY193	122.8	-1.0	0.4	0.4	GY
30	C01065	Maria x CY193	115.3	-0.7	3.1	0.7	GY
34	C02143	Cantate/Maria x 50	122.1	1.2	3.3	0.8	GB
35	C02145	Cantate/Maria x 50	134.3	2.0	8.2	-0.3	GB
36	C02146	Cantate/Maria x 50	119.7	0.3	4.3	1.2	GB
			2002	2002	2002	2002	
		#. of sites	5	3	2	1	

DSE = days to spike emergence; HT = plant height; LDG = lodging.
GB= glabrous hull, brown seed; GY = glabrous hull, yellow seed.

Table 4. Multi-year averages (1999-2002) for Canario lines in the C99000 series.
Data is presented relative to CDC Maria.

2002 TRT			GY	DSE	DPM	HT	LDG	2001 TWT	2001 KWT
1	CDC Maria		100.0	0.0	0.0	0.0	-0.0	0.0	0.0
2	C99005	Maria x CY184	103.1	0.3	0.1	-0.1	-0.0	-0.5	0.2
3	**C99037**	Maria x CY184	115.1	0.4	0.1	1.9	-1.2	1.0	0.2
4	**C99048**	Cantate x Maria	107.7	1.7	1.1	0.7	-1.2	-1.8	0.1
5	C99050	Cantate x Maria	112.0	1.4	1.5	2.2	-1.2	-1.4	0.3
	1999-2002	No. of sites	16	9	6	9	2	1	1

Table 5. Multi-year averages (2001-2002) for Canario lines in the C01000 series.
Data is presented relative to CDC Maria.

2002 TRT			GY	DSE	DPM	HT	LDG	LBL	KWT
1	CDC Maria		100.0	0.0	0.0	0.0	0.0	0	0.0
25	C01051	Maria x Cantate	111.5	0.3	0.4	-0.3	1.1	0	0.1
26	C01052	Maria x Cantate	100.3	0.7	0.8	3.3	0.5	-1	0.2
27	C01055	Cta/Mr//Cta	118.5	-0.5	1.1	0.1	-0.7	-1	0.4
28	C01061	Maria x CY193	139.9	0.8	0.1	0.3	1.1	0	0.1
29	C01062	Maria x CY193	131.3	0.4	0.6	-1.9	0.4	0	-0.1
30	C01065	Maria x CY193	144.6	0.5	0.1	2.3	0.7	0	0.0
31	C01074	Maria x 46	114.1	-0.3	-0.3	-0.7	4.6	0	-0.2
32	C01080	Cantate/Maria x 50	121.5	0.2	0.5	-0.6	1.4	0	0.4
		No. of sites 2001-2002	7	5	2 2001	4	1 2002	1 2000	1

Table 6. 2002 Redvers AgriArm site data; 3 replicate RCBD.
Data is presented relative to CDC Maria.

ENTRY	NAME	GY	DSE	DPM	HT
1	CDC Maria	100.0	0.0	0.0	0.0
2	C99005	119.7	0.0	0.0	3.7
3	C99037	123.2	-2.3	-1.7	6.4
4	C99048	142.0	0.0	0.0	5.4
5	C00030	100.1	2.4	1.6	5.7
6	C00035	130.7	-2.3	-1.7	3.4
7	C00041	113.1	0.0	0.0	4.0
8	C00046	130.8	-2.3	-1.7	3.4

Other lines (eg. C01061 and C01065) selected on the basis of high yield in 2001-2002; appeared to yield up to 45% higher than CDC Maria after 2 years (Table 5) of evaluation under drought conditions. The drought conditions, however, precluded selection for leaf mottle resistance in the breeding program.

Of the lines first evaluated in replicated trials in 2002 (series C02000), 39 were advanced for further evaluation in 2003.

Results from the 2002 trial at Redvers, SK (Table 6), were consistent with the larger data set in that C99037, C99048 and C00046 were higher yielding than CDC Maria.

The results for the most advanced lines evaluated in 2003 are presented in Table 7. The data is from trial CANYT1 grown at four sites. The data from the remaining four trials is not presented for the sake of brevity. The yield is expressed as a percent of the CDC Maria check and the other traits in relative (+/-) terms. Test weights and kernel weights were measured on lines advanced to 2004 yield trials. All lines were within 2 kg/hL units of CDC Maria for test weight, some had a kernel weight that exceeded that of CDC Maria by 1.5 mg per seed.

The trials grown at Scott were funded from CDC non-SADF resources.

Two lines previously identified as higher-yielding (C99037 and C99048) performed well in 2003 (Table 7). C99048 was subsequently registered as CDC Togo (see item b. below). C99037 appeared to be 3 to 4% higher yielding than CDC Togo (Table 7) but we did not proceed with this line since breeder seed production lagged behind that of C99048 as it needed to be reselected for the glabrous trait and suffered from residual heterozygosity for seed color.

Of the lines tested in CANYT1 in 2003, 20% were yellow-seeded genotypes. A number of these lines were equal in yield to CDC Togo and were advanced for further testing in 2004.

A number of lines that appeared very promising for grain yield in 2003 did not perform well in 2004. The line C02145 (Entry # 17 in Table 7) was 30% higher yielding than CDC Maria in 2002 (Table 3) but 7% lower yielding in 2003. This line has a large panicle and large flag leaf. It would appear that its later heading and maturity allowed it to take advantage of late rains in 2002. In 2003, however, limited rainfall during grain-filling resulted in haying-off. The nearly 40% variation for grain yield in C02145, relative to the control, from one year to the next is symptomatic of the yield-instability observed in this crop. We have used C02145 as a parent in our crossing blocks with the hope of combining its larger panicle size and flag leaf area with the earlier heading and maturity of other high-yielding lines.

Table 7. 2003 data for advanced Canario lines grown at four sites; data is presented relative to CDC Maria.

ENTRY	NAME	Pedigree	**Yield**	**DSE**	**DPM**	**HT**
1	CDC Maria		100.0	0.0	0.0	0.0
2	C99005	Maria x CY184	112.7	0.8	0.6	4.2
3	C99037	Maria x CY184	116.6	0.8	0.8	5.7
4	C99048	Cantate x Maria	112.6	3.1	2.0	5.7
5	C00030	Maria x CY193	113.3	1.1	0.7	4.8
6	C00034	Maria x CY193	111.7	0.3	1.1	3.8
7	C00038	Maria x 46	111.4	0.0	0.9	-0.8
8	C00091	Maria x 47	112.8	1.5	1.2	5.3
9	C01006	Maria x 27	114.2	2.6	2.7	3.0
11	C01025	Maria/CY184 x Maria/Cantate	114.3	1.5	1.2	4.3
13	C01061	Maria x CY193	110.2	0.9	0.5	1.7
14	C01062	Maria x CY193	113.1	2.1	0.3	6.8
15	C01065	Maria x CY193	118.6	1.2	0.8	3.8
17	C02145	Cantate/ Maria x 50	93.6	5.7	4.5	12.5
19	C02009	GY x 47	112.1	2.3	0.6	4.9
25	C02019	Cantate/Maria x 50	112.3	4.5	2.1	8.3
28	C02024	Cantate/Maria x 50	117.1	4.5	1.4	10.1
30	C02031	Cantate/Maria x 47	110.5	4.6	2.6	9.8
35	C02036	Cantate/Maria x 50	100.5	2.0	5.2	3.1
36	C01095	Maria x 50	104.4	1.6	1.9	2.6
	CANYT1	Number of sites =	4	4	3	3

As indicated earlier, record high grain yields were achieved at some sites in 2004. Under these growing conditions we determined that CDC Togo (C99048) maintained its yield advantage over CDC Maria, combined with a higher seed mass (Table 8). C99037, on the other hand, did not exhibit the 15% yield advantage observed during the previous five years, but still yielded 7% higher than CDC Maria. A number of yellow-seeded lines appeared to yield nearly 10% higher than CDC Togo and C99037 (Table 8). Lines C03058 and C03062 yielded 17% higher than CDC Maria but tended to be later maturing (by four days) and taller (5 to 9 cm). These lines were also high-yielding in 2003 (data not presented). Thus, it appears that we can achieve further yield gains, but there is a trade-off between yield and crop maturity and straw length.

Data summaries for C04000 series lines are presented in Table 9. These lines represent the final cycle of populations evaluated under the auspices of this project. These lines were retained for further testing because they appeared to offer a yield advantage over CD Togo or C99037.

Table 8. 2004 data for advanced Canario lines grown at four sites; data is presented relative to CDC Maria.

ENTRY	NAME	2004 CANYT#1	GY	DSE	DPM	HT	TWT	KWT	
1	CDC Maria		100.0	0.0	0.0	0.0	0.0	0.0	GB
2	C99005	Maria x CY184	98.5	0.1	-0.1	-0.6	0.5	0.1	GY
3	C99037	Maria x CY184	106.8	0.7	0.3	1.5	0.4	0.0	GB
4	C99048	Cantate x Maria	108.8	2.3	0.5	1.6	-0.1	0.7	GB
5	C00030	Maria x CY193	109.4	2.0	0.8	4.1	0.6	0.1	GY
7	C00038	Maria x 46	112.1	0.5	-0.8	-4.6	-0.2	0.1	GB
11	C01065	Maria x CY193	107.7	1.1	0.9	-0.5	0.4	0.1	GY
13	C02042	GY x 47	108.0	2.0	0.6	4.4	0.7	0.1	GY
16	C02066	GY x Cantate/Maria	108.2	1.6	1.2	2.1	0.4	0.4	GY
18	C02074	GY x Cantate/Maria	107.1	1.7	0.7	2.1	-0.3	0.5	GY
19	C02076	GY x Cantate/Maria	107.3	1.3	0.4	1.1	0.1	0.2	GY
21	C03006	GY x CY15	106.6	1.7	1.2	1.4	0.8	0.1	GY
27	C03028	C99005//Cant*3/Maria	112.1	3.0	1.7	2.0	0.7	0.5	GB
29	C03040	C99005//Cant*3/Maria	110.4	2.3	1.7	3.9	0.2	0.5	GY
30	C03042	C99005//Cant*3/Maria	107.2	2.4	1.3	2.1	0.1	0.6	GY
32	C03049	C99005//Cant*3/Maria	107.1	1.5	0.4	1.2	0.1	0.4	GY
35	C03058	Maria/CY184//CY186	116.9	3.6	2.8	5.1	0.2	0.2	GY
36	C03062	Maria/CY184//CY186	116.9	4.0	3.0	8.7	0.3	0.4	GY
		# of sites	5	4	4	4	4	4	

Table 9. 2004 data for selected C04000 series Canario lines grown at two or three sites; data is presented relative to CDC Maria.

ENTRY	NAME	2004 CANYT#2	GY	DPE	DPM	HT	TWT	KWT	
1	CDC Maria		100.0	0.0	0.0	0.0	0.0	0.0	GB
2	C99005	Maria x CY184	111.3	0.0	-0.1	-1.4	0.4	0.2	GY
3	C99037	Maria x CY184	118.4	0.7	1.3	-0.9	0.4	0.0	GB
4	C99048	Cantate x Maria	125.3	2.3	2.1	0.5	0.1	0.6	GB
8	C03087	Cantate*2/Maria//CY186	122.4	3.9	2.9	4.7	-0.4	0.5	GY
26	C04013	Cantate/Maria x 50	132.4	5.2	2.9	3.7	0.7	-0.6	GB
28	C04015	Cantate/Maria x 50	130.3	4.1	1.8	4.0	1.8	-0.4	GB
29	C04016	Cantate/Maria x 50	131.2	4.1	2.2	2.3	0.9	-0.4	GB
33	C04020	Cantate*3/Maria	121.4	1.4	2.5	-0.7	-0.9	0.6	GB
34	C04021	Cantate*3/Maria	121.6	1.2	3.1	-2.3	0.6	0.4	GB
		# of sites	3	2	2	2	3	3	

ENTRY	NAME	2004 CANYT3	GY	DSE	DPM	HT	TWT	KWT	
1	CDC Maria		100.0	0.0	0.0	0.0	0.0	0.0	GB
2	C99005	Maria x CY184	96.4	1.2	-1.1	-3.9	-0.8	0.0	GY
3	C99037	Maria x CY184	100.4	2.3	-0.6	0.7	-0.4	0.1	GB
4	C99048	Cantate x Maria	92.8	2.5	0.0	-2.4	-2.3	0.4	GB
9	C04028	Cantate*2/Maria//CY186	102.3	4.1	-0.4	2.9	-0.8	0.5	GY
14	C04033	Maria/CY184//CY186	109.9	4.5	2.5	7.3	-1.0	0.0	GY
16	C04035	Maria/CY184//CY186	105.0	3.4	1.5	5.3	-0.7	0.3	GY
21	C04040	Maria/CY184//CY186	103.4	4.6	1.[illegible]	3.6	-0.4	0.0	GY
25	C04044	Maria/CY184//CY186	102.6	2.3	0	3.9	0.8	0.3	GY
32	C04051	Cantate*2/Maria//CY186	106.6	5.4	.6	-1.1	-0.2	0.4	GY
		# of sites	3	2	2	2	3	3	

ENTRY	NAME	2004 CANYT#4	GY	DSE	DPM	HT	TWT	KWT	
1	CDC Maria		100.0	0.0	0.0	0.0	0.0	0.0	GB
2	C99005	Maria x CY184	103.9	0.4	1.3	-1.0	0.6	0.0	GY
3	C99037	Maria x CY184	111.9	1.0	1.1	-0.8	0.6	0.1	GB
4	C99048	Cantate x Maria	108.7	2.0	2.3	0.3	0.0	0.7	GB
7	C04058	Maria/CY184//CY186	121.4	3.3	0.4	4.8	1.3	0.0	GY
10	C04061	C99005/C99025	122.0	0.4	0.4	2.3	0.2	0.4	GY
12	C04063	Maria/CY184//CY186	123.3	3.4	2.0	5.9	0.4	0.6	GY
13	C04064	C99005/C99025	115.1	0.6	0.2	-0.7	0.0	0.1	GY
18	C04069	Cantate*4/Maria	115.3	2.3	2.2	3.5	0.4	0.7	GB
24	C04075	C99005/C99025	117.1	3.1	1.8	5.7	0.5	0.9	GY
25	C04076	Maria/CY184//CY186	125.8	3.4	2.9	2.2	0.8	0.5	GY
		# of sites	2	2	2	2	2	2	

(A.2) CDC Togo (C99048) glabrous canary seed

The experimental line C99048 was supported for registration in February 2004 and subsequently registered on June 10, 2004. This line is a higher yielding, heavier-seeded glabrous Canaryseed ("Canario") cultivar. It is now registered under the name CDC Togo.

CDC Togo was selected from the cross Cantate/CDC Maria made in 1995 at the University of Saskatchewan using the approach method in the greenhouse. The parent Cantate has pubescent hulls while CDC Maria has glabrous hulls. In the F2, putative F1-derived F2 families were screened for segregation of hull pubescence. Five out of 355 families segregated. The glabrous segregants were harvested and subsequently advanced in a growth room via single seed descent in the F3 generation. CDC Togo is derived from a bulked F_4 panicle hill which was tested in an F_5 plot in 1998. CDC Togo was evaluated in replicated yield tests from 1999 to 2003. The 2002 and 2003 trials were part of the current project.

CDC Togo is a glabrous annual canarygrass line that yielded, on average, 13.4 % higher than CDC Maria over 31 trials (Table 8) in Saskatchewan. CDC Togo had a 10.1 % higher seed mass than CDC Maria but 1.6 % lower test weight (Table 8).

Table 10. Agronomic performance of CDC Togo and CDC Maria in replicated tests, 1999-2003

Cultivar	Grain yield kg/ha	Heading days	Maturity days	Height cm	Test wt. kg/hL	Kernel wt. mg
CDC Maria	1049	53.5	94.0	86.4	69.1	7.30
CDC Togo	**1190**	**56.0**	**96.2**	**89.0**	**68.0**	**8.04**
# of sites	31	13	11	14	16	16

Testing protocols: In the absence of a Canaryseed Registration Test (as of 1994), testing was coordinated by the CDC, University of Saskatchewan. Four organizations contributed testing. Trials with grain yield Coefficients of Variation less than 20% (average CV = 9.3% over 31 tests) were retained.

C99037 glabrous canaryseed

As reported in the previous report section, C99037 is a glabrous canaryseed line that yielded 15% higher than CDC Maria over a five year (1999-2003) period (20 trials). In 2004, this line yielded slightly less or equal to CDC Togo. Averaged over 26 trials (1999-2004), C99037 yielded 2% higher than CDC Togo. The general trend has been for C99037 to perform well under drier conditions. Ultimately, a decision will need to be made as to whether C99037 warrants release as a cultivar for the drier canaryseed growing regions of Saskatchewan.

(A.3) Early generation yield trials

2001:

Approximately 520 experimental lines were grown in unreplicated yield trials with repeated checks at Kernen in 2001. The grain yield of the check plots was in the 100 to 200 kg/ha range. Lines which produced twice the yield of the closest check plot were retained for further testing in 2002. Nearly 270 lines were grown in 3.6 meter rows with repeated checks in 2001 at Kernen. The seed production from this material was limited to the point that it was insufficient for setting up yield plots in 2002.

2002:

Five hundred experimental lines were grown in unreplicated yield trials with repeated checks at Kernen in 2002. The grain yield of the check plots was in the 150to 200 kg/ha range. In excess of 500 lines were grown in 3.6 meter rows with repeated checks in 2002 at Kernen. Of the 500 lines grown in unreplicated plots in 2002, 100 were advanced for multi-site testing in 2003. Of the 500 lines in rows, 90 were advanced to unreplicated plots in 2003.

2003:

Approximately 90 experimental lines were grown in unreplicated yield trials at Kernen in 2003. The grain yield of the check plots (C99037) was in the 900 to 1200 kg/ha range. Lines which produced grain yields within one standard deviation of C99037 were retained for further testing in 2004. Approximately 180 lines were grown in 3.6 meter rows with repeated checks of C99037 (at Kernen). Of the experimental lines grown in unreplicated plots or rows in 2003, 80 were advanced for multi-site testing in 2004.

2004:

In excess of 600 lines were grown in unreplicated trials in 2004. The grain yield of the check plots (C99037) was in the 1000 to 2000 kg/ha range. Of the experimental lines grown in unreplicated plots 124 were advanced for multi-site testing in 2005. Approximately 180 lines were grown in 3.6 meter rows with repeated checks of C99037 (at Kernen). Of the 180 lines grown in rows, 79 were advanced for testing in unreplicated plot trials in 2005.

(A.4) Early generation nurseries

Four populations tracing to crosses made in 2000 were grown in bulk plots in 2002 and were bulk threshed. The seed was screened for the glabrous trait. Single panicles were harvested from the bulk populations for seeding in hills in 2003. A set (n=535) of F3, F4 populations and F5 populations were grown in hill plots in 2002. Each hill was bulk-threshed, then screened for the glabrous trait. These lines were grown in rows or hills in 2003, depending on seed availability. Approximately 1,200 hills were hand-seeded at the Seed Farm in 2003. This material was mainly in the F4 generation. The hills were selected on the basis of vigor and panicle size. The lines selected from the 2003 hill plots were subsequently evaluated in the 2004 unreplicated yield plots and rows (total of 780 lines). A population initiated during the winter of 2002/2003 (see A.5 below) were grown in F4 hill plots in 2004. A total of 3,000 lines were obtained from those 3 populations.

(A.5) Crossing block

There was no crossing block in 2001 due to a lack of funding. A crossing block was planted at the Seed Farm in 2002 but was abandoned due to severe drought/heat effects resulting in stunted plants with very small panicles. Two crossing blocks were attempted in the phytotron during the winter of 2002/2003 using Ethrel as a gametocide. Protocols published for wheat and barley were adapted (Hughes et al. 1976). In all crosses we used yellow-seeded lines as female parents and brown-seeded lines as pollen donors (Matus-Cadiz et al., 2003) in order to have morphological marker to identify hybrid plants in the F1 generation. Our crossing success was limited. However, a number of putative populations were generated and were checked for hybridity in the field in 2003. In excess of 2,000 seeds from three potential crosses were space-planted and screened for hybridity (brown seed color). We found three plants that were hybrids and subsequently segregated in the F2 generation when grown in the phytotron. The hybrids were from one cross (C00034/C02145). The F3 generation was advanced via Single Seed Descent and 3,000 F4 hills were subsequently hand-sown in the field in 2004.

A crossing block was planted at the Seed Farm in 2003. A portion of the crossing block was treated with two rates of ethrel in order to induce male sterility. Protocols described in the literature for wheat (Hughes et al., 1976) and barley were attempted. Both rates resulted in injury to the seedlings and a 2-week delay in heading. Thus we did not attempt to make controlled crosses with this material as the probability of success was quite low. Instead, we harvested the seed set on treated plants in bulk. There were six possible crosses. This seed was sown in low-density bulk plots in 2004 and was checked for hybridity at harvest-time. No hybrids were detected.

A series of crossing blocks were run in the phytotron in the winter of 2003-2004. One of those crossing blocks was performed using Ethrel treatment. We obtained a total of 380 putative F1 embryos from one attempted cross combination. That seed was space-planted in the field in 2004. In addition, we ran two crossing blocks using the approach method, assuming that we would get 1 to 2% out-crossing using glassine bags. Two approach methods were attempted. In total 11,151 seeds from 27 putative crosses

were space-planted in the field and were checked for hybridity. The average hybridity rate was 0.99% (0 to 5.13%). The highest hybridity was achieved with the application of a lower rate of ethrel. Seed from hybrid plants was grown in the F2 (checked for segregation) in the phytotron. In excess of 4,400 F3 hill plots were seeded to this material in 2005. Of the 27 crosses which were attempted, 22 were successful.

A crossing block (2 seeding dates) was planted in 2004 and treated with ethrel. Seed from that crossing block was retained and planted in the field in 2005.

In summary, 23 new canaryseed populations were generated during the course of this project. Most of these populations were from crosses made in 2003. Difficulties in crossing canaryseed continue to be a limiting factor in population development.

(A.6) Breeder seed production

Breeder seed production of C99048 and C99037 was initiated in 2002. Seed production of C99048 was two years more advanced than that of C99037. Approximately 200 kg of seed of C99048 was produced in 2002. Approximately 2 kg of C99037 breeder seed was produced in 2002. A larger breeder seed increase of C99048 was produced in 2003 in advance of the release of C99048 as CDC Togo in 2004. Breeder seed of C99037 was produced in 2003 and 2004. Should this line be released as a cultivar there will be sufficient breeder seed on hand.

Conclusions and Recommendations

During the course of this study, 50 replicated tests were conducted to evaluate the most promising canaryseed breeding lines. Each year (except 2003) 500 new lines were tested in unreplicated yield tests and approximately 20% were retained for testing in the multi-site replicated trials. Severe drought conditions during the first two years (2001 and 2002) resulted in very low grain yields (50-100kg/ha) in the nurseries where primary yield selection was performed (Kernen Crop Research Farm). Extreme growing conditions generally result in reduced selection efficiency since yield potential differences are masked. The growing conditions in 2003 resulted in yields that were 25-30% below average but provided more meaningful test results. In 2004 near-record high yields were achieved (2,400 kg/ha), allowing for yield potential differentiation. Despite these widely divergent growing conditions, a number of promising lines were identified and one variety was released during the course of the project.

CDC Togo (C99048) was registered in mid-2004. CDC Togo yielded, on average, 13% higher than CDC Maria (Table 10) and produced heavier seed. Thus, based on our earlier bench-mark (Hucl et al, 2001), CDC Togo appears to have closed the yield gap between glabrous and pubescent canaryseed varieties. This conclusion is based on the observed 12-15% yield difference between CDC Maria (glabrous) and Keet (pubescent) varieties.

Another experimental line (C99037) yielded an average of 2% higher than CDC Togo (over 26 trials 1999-2004). The general trend has been for C99037 to perform better under drier conditions. Ultimately, a decision will need to be made as to whether C99037 warrants release as a cultivar for the drier canaryseed growing regions of Saskatchewan. Based on testing performed in 2003 and 2004 we have identified lines that appear to yield up to 10% higher than CD Togo. Since these results are based on only one year of testing (4 or 5 sites) we will need to confirm the performance of these new lines. More agronomic data needs to be collected before deciding whether to release C99037 as a cultivar.

The general trend has been for these high-yielding lines to be a bit later-maturing and taller.

In addition to testing advanced lines to identify higher-yielding candidates, we were able to generate 22 new populations during the course of this project. In our first attempt we were foiled by drought (2002). In our second attempt we determined that the protocols reported for other cereals (wheat and barley) are not suitable for canaryseed under either field or controlled growth conditions. In our third and fourth attempts (2003 and 2004) we resorted to the approach pollination method with and without low rates of ethrel. The hybridity rates were in the 1-5% range. The inability to routinely generate new breeding populations is likely a major limiting factor in making genetic advances with this crop.

CDC Togo is the first cultivar released from a planned cross in North America and possibly, globally as no reports to the contrary are present in the published literature. CDC Togo is the first product from a breeding project initiated with funding from SADF (1994-1996; this project 2001-2005) and funding from AFIF and the Canadian Special Crops Association (1997-2001).

As can be seen from the above timeline summary, breeding efforts in canaryseed will require a longer-term financial and institutional commitment. Limited genetic variation within the current core collection (50 accessions) for the species (*Phalaris canariensis*) will require further population development. In addition, efforts need to be made to collect new accessions in the centers of origin and diversity of the crop. Yield instability and low harvest index are symptomatic of this crop. Baseline studies on the phenology and general development of the annual canarygrass plant are lacking. Funding sources appear to shy away from supporting this type of research as it is not seen as being cutting edge or of economic significance. In the long-run, these base-line studies will be required. In the shorter-term, obstacles to population development need to be overcome. Food uses for the crop remain to be validated.

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Administrative and Other Aspects:

Personnel -

L. Ehman - (January 1 - April 30, 2002) – 50%
(Technician) (February 7-June 30, 2003) – 100%
(July 1, 2003-June 30, 2004) – 60%
(July 1, 2004-June 30, 2005) – 10

M. Grieman (May 1, 2002 – August 30, 2003) – 50%
(Technician)
M. Matus-Cadiz (April 1, 2005 – June 30, 2005) – 100%

Other contributors: P. Hucl (December 1, 2001 – June 3, 2005) -5%

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Project Developed Materials: Nil.
Project photos: Nil
Expense statement: under separate cover from University of Saskatchewan Financial Services.